HIGGS OR DIJET PRODUCTION IN DOUBLE RAPIDITY GAP EVENTS[a]

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We quantify the rate of double diffractive Higgs/dijet production at pp (or $p\bar{p}$) colliders. The suppression due to QCD bremsstrahlung is calculated perturbatively up to single log accuracy. The survival probability of the rapidity gaps is discussed. A first comparison with experiment is made.

At first sight the process $p + p \to p+$ gap $+H+$ gap $+p$ looks to be a promising way to search for an intermediate mass Higgs boson. For such events the signal to background ratio is much better for the $H \to b\bar{b}$ channel since the background $b\bar{b}$ dijet rate is suppressed in double rapidity gap events due (i) to the absence of the colour octet $b\bar{b}$ state and (ii) to the polarization structure of double diffractive $b\bar{b}$ production (which has the same selection rules as $\gamma\gamma \to q\bar{q}$ process in the $J_z = 0$ channel, where the LO contribution vanishes [1]). Moreover here we have much better $b\bar{b}$ mass resolution than in an inelastic event where the presence of a large multiplicity of secondary particles tends to wash out the Higgs peak. On the other hand the cross section for the signal (and the background) are considerably suppressed [2,3] by the small survival probability of rapidity gaps, $W = S^2T^2$. First there is a probability S^2 that the gaps are not filled by soft rescattering, that is by an underlying interaction and, second, factor T^2 is the probability not to radiate extra gluons from the hard subprocess.

The basic mechanism for the process is shown in Fig. 1, where it turns out that the typical values of Q_t of the gluon, which screens the colour, are much smaller than M_H but are yet sufficiently large for perturbative QCD to be applicable. The corresponding longitudinal component x' satisfies $x'_\pm \ll x_\pm$, where light-cone fractions $x_\pm$ refer to the active gluons of the hard subprocess. The amplitude, to single log accuracy, is

$$\mathcal{M} \;=\; A\pi^3 \int \frac{d^2Q_t}{Q_t^4}\, f_g(x_+, x'_+, Q_t^2, M_H^2/4)\, f_g(x_-, x'_-, Q_t^2, M_H^2/4) \qquad (1)$$

where the $gg \to H$ vertex factor $A^2 = K(\sqrt{2}/9\pi^2)G_F\alpha_S^2(M_H^2)$ with the NLO

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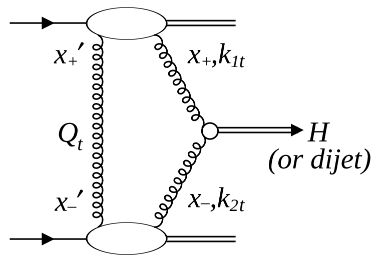

Figure 1:

K factor $K \simeq 1.5$. The unintegrated gluon densities take the form [3]

$$f_g(x, x', Q_t^2, M_H^2/4) \;=\; R_g \, \frac{\partial}{\partial \ln Q_t^2} \left[\sqrt{T(Q_t, M_H/2)}\, xg(x, Q_t^2) \right] \qquad (2)$$

where $\sqrt{T}$ arises because the survival probability is only relevant to the hard gluon. The multiplicative factor R_g is the ratio of the skewed $x' \ll x$ integrated gluon distribution to the conventional one, $xg(x, Q_t^2)$. $R_g \simeq 1.2(1.4)$ at LHC (Tevatron) energies. Finally the bremsstrahlung survival probability T^2 is given by

$$T(Q_t, \mu) \;=\; \exp\left(- \int_{Q_t^2}^{\mu^2} \frac{\alpha_S(k_t^2)}{2\pi} \, \frac{dk_t^2}{k_t^2} \int_0^{1-k_t/\mu} zP_{gg}(z) dz \right). \qquad (3)$$

In practice we also include the quark contribution, see [3] for this and other details. At first sight integral (1) appears divergent at small Q_t. However the Sudakov form factor T strongly suppresses the infrared contribution. The saddle points of the integral are located near $Q_t^2 = 3.2(1.5)$ GeV^2 at LHC (Tevatron) energies.

It is important to emphasize that the double diffractive process does not satisfy conventional factorization properties. We see amplitude (1) satisfies Q_t factorization. However even this is violated when soft rescattering effects are included.

Amplitude (1) is written for the exclusive process where $k_{1t} \simeq k_{2t} \simeq Q_t$. The modification for the inclusive process, $pp \to X+$ gap $+H+$ gap $+Y$, is given in [3,2] where it was found that the cross section is much larger.

Our most recent calculation [3] was performed to single log accuracy and used more realistic unintegrated skewed gluons, which enhances the cross sec-

tion as compared to previous results [2,4]. We have compensation of the factorization and renormalisation scale dependences between the NLO vertex A and the Sudakov form factor T. All this considerably increases the stability of our perturbative predictions of the cross sections, and we anticipate the higher order α_S effects will give, at most, about $\pm 40\%$ uncertainty.

The main uncertainty arises from the survival probability S^2 of the rapidity gaps with respect to soft rescattering effects. This effect was extensively studied, see for example [3,5]. It is model dependent and reflects the spatial distribution taken for gluons in the proton. An optimistic estimate is $S^2 = 0.1$, which we used as the default value, but most probably the actual value is lower and even $S^2 = 0.01$ is not excluded [3]. Assuming $S^2 = 0.1$ we find, for m(Higgs) $= 120$ GeV, that σ(exclusive) $= 5.7$ fb at the LHC energy. On the other hand for inclusive production the cross section is of the order of 100 (10) fb, taking rapidity gaps $\Delta\eta = 2(3)$.

A closely related observable process is the double diffractive central production of a pair of high E_T jets with rapidity gaps on either side of the pair. Essentially we simply replace the $gg \to H$ subprocess by that for $gg \to$ dijet. The dijet rate is much larger than that for Higgs and so collider experiments should be able to directly test the QCD estimates [4,3] and measure S^2.

A search for double diffractive dijet events was reported [6] at this Workshop. The upper limit for such events at the 95% CL is 3.7 nb for E_t(jet) > 7 GeV. It was noted that this cross section is $\mathcal{O}(10^3)$ smaller than the theoretical calculation presented[b] in [7]. This theoretical model, together with those of refs. [8,9] for Higgs production, uses a non-perturbative two-gluon Pomeron approach where the gluon propagator is modified so as to reproduce the total pp cross section. It is known that such a non-perturbative gluon normalisation will overestimate the double diffractive cross section [3,7]. On contrary, a realistic unintegrated gluon density, determined from conventional gluons of global parton analyses, was used in [3]. There a much smaller cross section was anticipated. Indeed for the CDF kinematics we predict an exclusive dijet cross section of about 1 nb, taking $S^2 = 0.1$, which may be enhanced by up to a factor of 2 to allow for proton/antiproton dissociation. Unlike other approaches this prediction is well within the experimental limit.

Another check of our perturbative approach is the behaviour of the dijet cross section with E_T (jet). Due to the x dependence of the perturbative gluon, we predict a steeper E_T fall off than the non-perturbative model. Our results also show [3] a strong increase of double diffractive processes with increasing energy, that again arises because of the growth of gluon densities with increasing $1/x \simeq s/M^2$, which is advantageous for the LHC. On the contrary

[b] It was stressed [7] that this calculation does not include the survival probability S^2.

the predictions of the non-perturbative approaches[8,7,9] depend only weakly on energy through the energy dependence of the "soft" cross section which was used to normalise the two-gluon exchange amplitude.

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References

1. D. Borden et al., *Phys. Rev.* D**50**, 4499 (1994);
   V. S. Fadin, V. A. Khoze and A. D. Martin, *Phys. Rev.* D**56**, 484 (1997).
2. V. A. Khoze, A. D. Martin and M. G. Ryskin, *Phys. Lett.* B**401**, 330 (1997).
3. V. A. Khoze, A. D. Martin and M. G. Ryskin, *Eur. Phys. J.* C, `hep-ph/0002072`.
4. A. D. Martin, M. G. Ryskin and V. A. Khoze, *Phys. Rev.* D**56**, 5867 (1997).
5. E. Gotsman, E.M. Levin and U. Maor, *Phys. Lett.* B**353**, 526 (1995).
6. K. Borras, these proceedings.
7. A. Berera, `hep-ph/9910405`.
8. A. Bialas and P.V. Landshoff, *Phys. Lett.* B**256**, 540 (1991).
9. E.M. Levin, `hep-ph/9912403`.